# Floods of November 1990 in Western Washington

By Larry L. Hubbard

U.S. GEOLOGICAL SURVEY Open-File Report 93-631

# U.S. DEPARTMENT OF THE INTERIOR BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY GORDON P. EATON, Director

For additional information write to:

District Chief U.S. Geological Survey, WRD 10615 S.E. Cherry Blossom Drive Portland, Oregon 97216 Copies of this report can be purchased from:

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#### CONVERSION FACTORS AND VERTICAL DATUM

Ву	To obtain	
25.4	millimeter	
0.3048	meter	
1.609	kilometer	
2.590	square kilometer	
0.02832	cubic meter	
0.02832	cubic meter per second	
	25.4 0.3048 1.609 2.590 0.02832	25.4 millimeter 0.3048 meter 1.609 kilometer 2.590 square kilometer 0.02832 cubic meter

Sea level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929—a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

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#### **ABSTRACT**

During November 7-11, a moistureladen warm front created heavy rains and melting snows which resulted in appreciable flooding in northwestern Washington and in the Wenatchee River basin that drains the east slopes of the Cascade Range. The Skagit Basin on the west slope of the Cascade Range was affected the most during this storm. After this storm, cool, wet weather lasted until November 21 and resulted in another low-elevation mountain snowpack. A second warm, wet front arrived on November 21 and lasted through November 25, resulting in extreme flooding; a larger area was affected by this storm. The most extensive flooding from these storms occurred in the Duwamish, Lake Washington, Snohomish, and Wenatchee River basins. Record peak flows were recorded at 11 gaging stations. At six gaging stations, the peak flows are estimated to have recurrence intervals of about 100 years.

Two lives were lost in the second flood (November 23-26, 1990) when thousands of people were evacuated from their homes to escape floodwaters. Some residents of Fir Island, near the mouth of the Skagit River, were evacuated from their homes during both of the floods. In both floods, heavy damages were sustained. The floodwaters destroyed homes, roads, bridges, levees, farm crops, and livestock. Estimated damages were about 42 million dollars for the November 9-11 flood, and about 100 million dollars for the flood of November 23-26.

#### INTRODUCTION

Above-average precipitation, during October and early November 1990, saturated soils and created a low-elevation mountain snowpack that set the stage for the floods that followed. The flooding described in this report covered most of western Washington and the Chelan and Wenatchee River Basins (pl. 1). The Chelan and Wenatchee River Basins drain the east slopes of the Cascade Range and are not considered part of western Washington. Western Washington is defined as all parts of the State west of the crest of the Cascade Range. The extreme southern portion of western Washington experienced relatively mild flooding and is not included in this study. Major floods in western Washington typically occur during the winter months and are usually caused by eastward moving storms (from the Pacific Ocean) embedded in frontal systems. When these winter storms are accompanied by warm temperatures and the rain falls on a heavy snowpack on the west slopes of the Cascade Range, flooding is greatly intensified. Flooding on the east slopes of the Cascade Range can result directly from these winter storms, spring snowpack runoff, or convection storms.

The purpose of this report is to document the flooding that occurred in November of 1990, and to describe the storms, the flooding, and the flood damages. A map (pl. 1) showing the location of flood measuring sites and location of selected precipitation measuring stations also is included in this report. Flood peak stages and discharges of the affected streams and those of previous floods of record are tabulated. Total rainfall for November 8-11, 1990, and November 19-27, 1990 is shown for 10 sites. Daily precipitation at two weather stations and flood discharges for 46 stream-gaging stations are included.

Three separate major flood events occurred in Washington during the 1990 calendar year. The peak flows of January 1990 were reported by Hubbard (1991) and are not described in this report.

# DETERMINATION OF FLOOD STAGES AND DISCHARGES

Peak stages and discharges were obtained and compiled using standard procedures of surface-water investigations used by the USGS. The usual method of determining stream discharge is the application of a stage-discharge relation to a known stage. That relation at a station is usually defined by current-meter measurements through as much of the range in stage as possible. If the peak discharge is above the range of the measured discharge, the stage-discharge relation may be extended by logarithmic extrapolation, by velocity-area studies, or by the use of other hydraulic techniques. Peak discharges that are far beyond the range of the stage-discharge relation at the gaging stations may be determined by various types of indirect measurements. During major floods, such as the November 1990 floods in western Washington, adverse conditions often make it impossible to obtain current-meter measurements near flood peaks at some sites. Peak discharges at a few of the sites in flooded areas were determined by indirect methods based on detailed surveys of selected channel reaches after the flood had subsided. Descriptions of the indirect measurement methods used by the USGS are given in a series of publications titled "Techniques of Water-Resources Investigations of the United States Geological Survey, Book 3."

#### **EXPLANATION OF DATA**

Peak stages and discharges for the November 1990 floods are listed in table 1. The first major division of columns in table 1 under "Maximum floods" provides information on known floods prior to those of November 1990 and includes period of record, gage heights, and discharges for maximum floods for each measurement location. More than one period of record is shown for some stations. The second

major division under "Maximum floods" includes information on date, gage height, discharge, and recurrence interval for the November 1990 floods.

The recurrence interval is the average interval, in years, in which a flood of a given magnitude will be equalled or exceeded once. A flood having a recurrence interval of 50 years can be expected to occur, on the average, once in 50 years, or it can be described as one that has a 2-percent chance of being equalled or exceeded in any one year. All recurrence intervals in the tables were determined using guidelines for determining flood frequency as shown in a report by the U.S. Water Resources Council (1981).

#### THE STORM SYSTEMS

Above-average precipitation in October and early November resulted in saturated soils that contributed to the flooding potential when the major storms arrived during the periods of November 7-11 and 21-25, 1990. The daily precipitation record for the National Weather Service climatological station at Mud Mountain Dam (climatological station number 5) illustrates the large quantity of precipitation during October and November (fig. 1). The above-normal precipitation in western Washington during October and November 1990 is documented by the 1990 annual records of the U.S. National Oceanic and Atmospheric Administration (1990c). For example, the total precipitation for October and November at Mud Mountain Dam was 23.42 inches. This precipitation was 12.05 inches greater than the normal precipitation of 11.36 inches for this period (about 200 percent of normal) and was similar to the precipitation that occurred at other sites in the area. For the same period, recorded precipitation at Grays River Hatchery (climatological station number 1) was about 140 percent of normal; and Lake Wenatchee, the easternmost climatological station (number 9), recorded about 250 percent of normal precipitation.

**Table 1.** Flood stages and discharges, November 9-11 and 23-26, 1990, in Washington  $[mi^2 = \text{square miles}, \, ft^3/s = \text{cubic feet per second}, \, > = \text{greater than}, \, -- = \text{missing data}, \, e = \text{estimated}]$ 

							Maximum floods	spoc			
				Known before November 1990	re Nover	nber 1990			N	November 1990	
Number Map	ber Station	Stream and place determination	Drainage area (mi²)	Period of record	Year	Gage height (feet)	Discharge (ft³/s)	Date	Gage height (feet)	Discharge (ft³/s)	Recurrence interval (years)
				Naselle River Basin	ver Basin						
_	12010000	Naselle River near Naselle, Washington	54.8	1929-90	1935	;	11,100	Nov. 24	18.45	11,300	50
				Willapa River Basin	ver Basin						
2	12013500	Willapa River	130	1948-54	1949	:	11,400	Nov. 24	24.21	11,800	15
		near Willapa, Washington		19 <b>5</b> 7-58 1961-90	1958 1990	1 1	7,360				
				Chehalis F	Chehalis River Basin						
ю	12020000	Chehalis River near Doty, Washington	113	1939-90	0661	19.96	27,500	Nov. 24	17.45	20,600	25
4	12025000	Newaukum River near Chehalis, Washington	155	1942-90	9861	12.76	10,700	Nov. 24	12.73	10,300	25
v	12025700	Skookumchuck River near Vail, Washington	40.0	1967-90	1972	10.93	006'9	Nov. 24	10.30	5,820	20
9	12027500	Chehalis River near Grand Mound, Washington	895	1928-90	1990	19.34	68,700	Nov. 25	18.12	48,000	20
7	12031000	Chehalis River at Porter, Washington	1,294	1952-72 1974-84	1972 1975	23.88 23.36	55,600 48,100	Nov. 26	23.17	43,000	10
		1		1986-90	1990	24.52	60,400				
<b>∞</b>	12035000	Satsop River near Satsop, Washington	299	1929-90	1935	38.9	46,600	Nov. 24	35.75	38,200	10
				Quinault F	Quinault River Basin						
6	12039500	Quinault River at Quinault Lake, Washington	264	1911-90	1955	20.51	50,200	Nov. 10 Nov. 24	18.35 18.15	41,400	15 15
				Queets River Basin	er Basin						
01	12040500	Queets River near Clearwater, Washington	445	1930-67 1974-90	1935 1986	27.0 24.40	130,400	Nov. 10 Nov. 23	24.19 25.44	99,000	10 25
				Hoh River Basin	Basin						
11	12041200	Hoh River at U.S. Highway 101, Washington	253	1960-90	1979	19.08	51,600	Nov. 10 Nov. 24	18.18 19.61	47,300 54,500	7 15
				Quillayute	Quillayute River Basin	in					
12	12043000	Calawah River near Forks, Washington	129	1897-01							
				1976-80 1984-90	1979	18.98	28,900 27,900	Nov. 10 Nov. 23	18.12 20.58	25,900 34,500	7 20
		er j		Elwha River Basin	er Basin						
13	12045500	Elwha River at McDonald Bridge near Port Angeles, Washington	269	1897-01 1918-90	1897 1949	24.20	41,600 30,000	Nov. 23	23.71	28,700	15

Table 1. Flood stages and discharges, November 9-11 and 23-26, 1990, in Washington—Continued

							Maximum floods	spoo			
			_	Known before November 1990	ore Nover	nber 1990			z	November 1990	
Number	ıber	Stream and place	<b>Drainage</b> area	Period		Gage height	Discharge		Gage	Discharge	Recurrence
Мар	Station	determination	(mi²)	record	Year	(feet)	(ft <sup>3</sup> /s)	Date	(feet)	(ft³/s)	(years)
				Dungenes	Dungeness River Basin	ij					
14	12048000	Dungeness River near	156	1923-30	1924	:	6,340	Nov. 24	8.35	7,120	25
		Sequim, Washington		1937-90	1949	8.58	6,820				
				Duckabus	Duckabush River Basin	sin					
15	12054000	Duckabush River near	9.99	1938-90	1949	10.06	8,960	Nov. 10	7.26	4,460	2 9
		Limion, washington		Nisqually	Nisqually River Basin	<b>=</b>		NOV. 23	t 0:0	No.,c	n
16	12082500	Nisqually River near National, Washington	133	1942-90	1977	11.96	17,100	Nov. 24	10.23	11,000	10
17	12083000	Mineral Creek near Mineral, Washington	75.2	1942-90	1990	13.56	13,800	Nov. 24	12.78	10,000	25
				Puyaliup F	Puyallup River Basin	_					
18	12093500	Puyaliup River near Orting, Washington	172	1931-90	1962	11.82	15,300	Nov. 24	10.19	10,300	S
19	12095000	South Prairie Creek at South Prairie, Washington	79.5	1950-71	1955	33.55	6,850	Nov. 24	32.45	5,560	10
70	12099600	Boise Creek	15.4	1977-81	1979	3.25	545	Nov. 24	3.38	571	2
21	12101500	Puyallup River	948	1914-90	1933	or:c :	57,000	Nov. 24	27.19	41,900	15
		at ruyanup, wasmington		Duwamish	Duwamish River Basin	ij					
22	12112600	Big Soos Creek above Hatchery near Auburn, Washington	66.7	1960-90	1990	7.55	1,750	Nov. 25	7.16	1,570	30
				Lake Wash	Lake Washington Basin	sin					
23	12117500	Cedar River near Landsburg, Washington 1990	121	1895- 1990	1911	:	14,200	Nov. 24	10.38	10,800	70
24	12119000	Cedar River at Renton, Washington	184	1945-90	1975	14.14	8,800	Nov. 24	17.13	10,600	100
25	12121600	Issaquah Creek near mouth near Issaquah, Washington	9.99	1963-90	1990	13.50	3,200	Nov. 24	13.43	2,410	S
				Snohomis	Snohomish River Basin	sin					
56	12134500	Skykomish River near Gold Bar, Washington	535	1928-90	1980	21.38	90,100	Nov. 10 Nov. 24	21.01	86,800 102,000	20 50
27	12141300	M.F. Snoqualmie River near Tanner, Washington	154	1961-90	1959	18.7	49,000	Nov. 10 Nov. 24	12.76 14.97	21,000	\$ \$
28	12142000	N.F. Snoquaimie River near Snoqualmie Falls, Washington	64.0	1929-90	1932	:	15,800	Nov. 9 Nov. 24	11.32	10,400 12,000	5 10
53	12143400	S.F. Snoqualmie River near Garcia, Washington	41.6	1960-90	1986	ı	8,450	Nov. 9 Nov. 24	17.18	6,240 8,000	5 15

Table 1. Flood stages and discharges, November 9-11 and 23-26, 1990, in Washington—Continued

Number   Column   C								Maximum floods	spoo			
Station				-	Known befc	ore Nove	mber 1990			z	ovember 1990	
Shailon   Getermination   Conf.   Fracord   Vest (1842)   (1754)   Date (1844)   (1754)   (	ž	nber	Stream and place	Drainage area	Period		Gage height	Discharge		Gage height	Discharge	Recurrence interval
12145500   Stocyalalinic River   275   Stocyalalinic Riv	Мар	Station	determination	(mi²)	record	Year	(feet)	(ft³/s)	Date	(feet)	(ft³/s)	(years)
12145500   Stapphalmin Riverr   375   1958-90   1978   61,000   Nov. 21   215.55   49,100   Nov. 22   215.55   49,100   Nov. 22   215.55   49,100   Nov. 22   215.55   49,100   Nov. 22   215.55   23,000   Nov. 23   215.55   23,000   Nov. 23   215.55   23,000   Nov. 23   215.55   23,000   Nov. 24   215.55   23,000   Nov. 24   215.55   23,000   Nov. 25   215.55   23,000   Nov. 25   215.00					Silonomis	I WINCI DA		וכת				
12145000   Team and administration of the control	30	12144500	Snoqualmie River	375	1958-90	1959	19.78	61,000	Nov. 10	18.23	49,100	5 60
12145500   Regain River rear			ileal Biloqualitie, washington						MOV. 24	CC: 17	000,07	OC .
12150800   Sinqualnie River   1, 577   1921, 923   99, 81, 95, 90   Nov. 10   99, 48   51,000   61,0	31	12145500	Raging River near Fali Citv, Washington	30.6	1945-90	1986	6.27	5,330	Nov. 10 Nov. 24	5.72	3,900 6,220	150
1218980   Sank Brief mear   1,537   1921     180,000e   Nov. 16   67,00   65,200   1218980   Nov. 16   67,00   65,200   1218980   Nov. 16   67,00   67,000   65,200   1218980   Nov. 16   67,00   1752   1752   1750   Nov. 16   17,000   17,000   Nov. 16   17,000   17,000   Nov. 16   17,000   Nov. 17   18,100   Nov. 18   18,100   Nov. 18   18,100   Nov. 18   18,100   Nov. 19   18,100   No	Ω	12140000	Snoomalmia Divar	603	1078.00	1022	88.05	20 500	Now 10	50.48	53,000	<u> </u>
12189600   Sauk River near   1,537   1921   1921     180,000e   Nov. 21   2,530   190,000   15,840   180,000	70	12149000	official miner of the second o	606	06-0761	1932	09.90	000,80	Nov. 24	60.70	65,200	25
12186500   Sauk River near   152   153-90   1975   22.92   115,000   Nov. 25   25.30   150,000     12186500   Sauk River near   152   1917.22   1980   16.03   40.100   Nov. 21   12.56   23,600     12186500   Sauk River near   171   1928-90   1980   16.03   40.100   Nov. 21   12.56   23,600     12186500   Sauk River near   171   1928-90   1980   16.03   40.100   Nov. 21   12.56   63,800     12186500   Stagil River near   171   1928-90   1980   15.04   15.040   Nov. 21   15.99   145,000     12200500   Stagil River near   171   1928-90   1980   15.040   15.040   Nov. 21   15.99   145,000     12200500   Stagil River near   171   1928-90   1991   15.040   15.040   Nov. 12   15.90   140,000     12210500   Nocleack River at   271   1912-15   15.60   15.000   Nov. 11   15.61   172,000     12451000   Steehkin River near   271   1910-15   1910   15.60   172,000   Nov. 11   15.60   172,000     12451000   Steehkin River at   10.00   1928-90   1948   12.48   12.40   Nov. 21   14.87   17.00     1245200   Wenachee River at   1.00   1928-90   1948   12.48   12.40   Nov. 21   14.87   17.00     12452200   Cossiliz River at   1.00   1928-90   1948   12.48   12.40   Nov. 21   12.45   17.50     14252300   Cossiliz River at   1.00   1928-90   1973   12.48   12.48   12.40   Nov. 21   12.48   12.50     14252300   Cossiliz River near   1.00   1928-90   1973   12.48   12.40   Nov. 25   12.49   12.50     14252300   Cossiliz River near   1.00   1928-90   1973   12.48   12.40   Nov. 25   12.49   12.50     14252300   Cossiliz River near   1.00   1928-90   1973   17.00   Nov. 25   12.44   17.500     14252300   Cossiliz River near   1.00   1928-90   1977   12.48   12.40   17.44   17.500     14252300   Cossiliz River near   1.00   1928-90   1977   12.51   12.40   17.50   19.50   19.77   12.51   12.50   19.50   19.77   12.50   19.70   19.77   12.51   12.50   19.70   19.77   12.50   19.70   19.77   12.50   19.70   19.77   12.50   19.70   19.77   12.50   19.70   19.77   12.50   19.70   19.77   12.50   19.77   12.50   19.77   12.50   19.77   12.	33	12150800	Snohomish River	1,537	1921	1921	;	180,000e	Nov. 10	21.65	100,000	15
12186000   Sauk River maar   152   1917-22   1918-22			near Monroe, Washington		1963-90	1975	22.92	115,000	Nov. 25	25.30	150,000	100
12166000   Stank River near   152   1917-22					Skagit Riv	er Basin						
12199500   Stagit River mean   714   1928-90   1980   16.03   40,100   Nov. 24   12.56   24,600   12194000   Stagit River mean   2,737   1312-40   1980   18.24   98,600   Nov. 10   15.99   149,000   12194000   Stagit River mean   2,737   1312-40   1940   1951   36.85   144,000   Nov. 24   16.99   182,400   1950   132,4000   Nov. 24   16.99   182,4000   Nov. 24   16.99   182,4000   Nov. 25   18.99   146,000   1950   1	34	12186000	Sauk River near	152	1917-22				Nov. 10	11.90	22,000	15
1219500   Sauk River near   714   1926-90   1980   18.24   98,600   Nov. 21   15,64   69,800   12104000   Sauk River near   7,777   1815   1815   69,3   50,0000   Nov. 21   19,000   19,000   12,0000   Nov. 10   19,000   19,000   19,000   19,000   Nov. 10   19,000   19,000   Nov. 10   19,000   19,000   Nov. 10   19,000   Nov. 10   19,000   19,000   Nov. 10   19,000   Nov. 20   19,000   Nov. 20			Darrington, Washington		1928-90	1980	16.03	40,100	Nov. 24	12.56	24,600	20
12006000   Stagit River near   2,777   1815   1815   693   500,000   Nov. 24   9.949   149,000   Nov. 24   149,000   Nov. 24   149,000   Nov. 24   149,000   Nov. 24   148,000   Nov	35	12189500	Sauk River near Sauk, Washington	714	1928-90	1980	18.24	009'86	Nov. 10 Nov. 24	15.64 16.99	69,800 83,400	20 40
Concrete, Washington   1924-90   1949   40.80   154,000   Nov. 24   39.89   146,000   Nov. 25   34,000   Nov. 26   34,000   N	36	12194000	Skagit River near	2,737	1815	1815	69.3	200,000	Nov. 10	40.20	149,000	30
12210500   Stagis River rear   3,093   1906   1906   37.0   180,000   Nov. 11   36.61   142,000   Nov. 12   37.37   152,000   Nooksack River at   1932   1932   18.8   49.300   Nov. 10   15.40   37.900   12451000   Stehekin River rear   32.1   1910-15   15.69   43.200   Nov. 10   15.40   37.900   12457000   Stehekin River rear   32.1   1910-15   1926-90   1948   19.30   Nov. 24   14.87   35.100   Nov. 24   14.87   35.100   Nov. 24   14.87   37.900   Nov. 25   10.800			Concrete, Washington		1924-90	1949	40.80	154,000	Nov. 24	39.89	146,000	25
12451000   Novksack River at Set 1932   158   144,000   Nov. 25 37.37   152,000   Nov. 24   1487   35,000   Nov. 24   27.45   14.700   Nov. 25   27.45   14.700   Nov. 25   27.45   27.400	37	12200500	Skagit River near	3,093	1906	1906	37.0	180,000	Nov. 11	36.61	142,000	50
12451000   Nooksack River at S84   1922   1932   16.8   49,300   Nov. 10   15.40   37,900   Stehckin River near   321   1910-15   Stehckin River state   321   1910-15   Stehckin River state   321   1910-79   1948   12.40   Nov. 10   2.661   12,800   Nov. 24   14.87   35,100   Nov. 24   14.87   35,100   Nov. 24   14.87   35,100   Nov. 24   14.87   12,800   Nov. 24   14.700   Nov. 11   10.52   17,000   Nov. 11   10.50   17			Mt. Vernon, Washington		1940-90	1951	36.85	144,000	Nov. 25	37.37	152,000	75
12451000   Nooksack River at borning, Washington   1935-90   1951   15.69   49,200   Nov. 10   15.40   37,900   37,900   12451000   Stehekin River near   321   1910-15   1947   17.00   Nov. 24   14.87   35,100   1926-90   1948   12.48   22,700   Nov. 11   10.22   17,000   1926-90   1948   12.48   22,700   Nov. 11   10.52   17,000   1926-90   1948   12.48   22,700   Nov. 11   11.87   20,000   Nov. 11   11.87   20,000   Nov. 11   11.87   20,000   Nov. 12   17.88   20,000   Nov. 13   12.48   20,000   Nov. 14   12.49   20,000   Nov. 14   22.49   20,000   Nov. 15   22.49   22,000   Nov. 16   22.49   22,000   Nov. 16   22.49   22,000   Nov. 17   22.49   22,000   Nov. 25   22.49   22,000   Nov. 26   22.49   22,000   Nov. 26   22.49   22,000   Nov. 26   22.49   22,000   Nov. 26   22.49   22,000   Nov. 27   22.49   22,000   Nov. 27   22.49   22,000   Nov. 28   22.49   22,000   Nov. 28   22.49   22,000   Nov. 28   22.49   22,000   Nov. 28   22.49   22,000   Nov. 29   22.49   22,000   22.500   Nov. 24   22.49   22,000   22.500   Nov. 24   22.49   22,000   22.500   Nov. 24   22.49   22.500					Nooksack	River Bas.	. <b>E</b>					
12451000   Stehekin River near   321   1910-15   Stehekin Washington   1926-90   1948   12.48   22,000   18,900   Nov. 10   26,61   12,800   1245000   Wenatchee River at   1,000   1929-90   1948   12.48   22,700   Nov. 11   11,87   20,000   1245000   Wenatchee River at   1,000   1929-90   1948   12.48   32,300   Nov. 11   11,87   20,000   Nov. 25   14,39   33,200   Nov. 11   11,87   20,000   Nov. 12   14,290   Nov. 11   11,87   20,000   Nov. 12   14,390   Nov. 13   14,390   Nov. 14   14,390   Nov. 14   14,390   Nov. 15   14,390   Nov. 15   14,390   Nov. 15   14,390   Nov. 15   14,390   Nov. 16   14,390   Nov. 17   14,390   Nov. 18   14,390   Nov. 25   14,490   Nov. 25   Nov. 2	38	12210500	Nooksack River at	584	1932	1932	16.8	49,300	Nov. 10	15.40	37,900	10
12451000   Stehekin River near   321   1910-15   Stehekin River near   321   1910-15   Stehekin River near   321   1910-15   Stehekin River near   S91   1910-79   1948   12.48   22.700   Nov. 10   10.55   14.700   Nov. 24   27.45   14.700   Nov. 25   14.30   1910-79   1948   12.48   22.700   Nov. 11   11.87   20.000   Nov. 25   14.39   33.200   Nov. 25   14.39   33.200   Nov. 25   14.39   33.200   Nov. 25   14.39   33.200   Nov. 25   17.58   40.000   Nov. 25   17.50   Nov.			Deming, Washington		1935-90	1951	15.69	43,200	Nov. 24	14.87	35,100	<10
12451000   Stehekin River near   321   1910-15   1948   29,000   18,900   18,900   18,900   18,900   18,900   19,400					Chelan Riv	ver Basin						
12457000   Wenatchee River at Store   1926-90   1948   12.48   22.700   Nov. 14   10.52   17,000	39	12451000	Stehekin River near	321	1910-15				Nov. 10	26.61	12,800	5
Wenarchee River at 12457000         Wenarchee River at 1591         591         1910-79 1948         12.48 22,700         Nov. 11         10.52 17,000         17,000           Plain, Washington 1245500         Wenarchee River at 1246250         1,000         1929-90         1948         15.88 32,300         Nov. 11         11.87 20,000           Peshastin, Washington 1246250         Wenarchee River at 1246250         1,301         1,962-90         1980         27.23 29,600         Nov. 11         11.87 20,000           14226500         Cowlitz River near Packwood, Washington 142250         Cowlitz River near 1287         1929-90         1974         12.58 21,700         Nov. 25 29.80         45,900           14232500         Cowlitz River near Packwood, Washington 142350         1929-90         1974         12.58 21,700         Nov. 25 23.60         66,300           1423260         Tillon River above Bear 141         1956-90         1977         26.54 89,300         Nov. 25 23.60         66,300           Tillon River above Bear Cinebar, Washington Cowlitz River near Cinebar, Washington Cinebar, Was			Stehekin, Washington		1926-90	1948	29.00	18,900	Nov. 24	27.45	14,700	10
12457000         Wenatchee River at Plain, Washington         591         1910-79         1948         12.48         22,700         Nov. 11         10.52         17,000           Plain, Washington         Peshastin, Washington         1,000         1929-90         1948         15.88         32,300         Nov. 11         11.87         20,000           Peshastin, Washington         Wenatchee River at Pockwood, Washington         1,301         1962-90         1980         27.23         29,600         Nov. 11         25.42         21,500           Monitor, Washington         Cowlitz River near Packwood, Washington         287         1929-90         1974         12.58         21,700         Nov. 24         12.48         28,700           1423550         Cispus River near         287         1929-90         1974         12.58         21,700         Nov. 24         12.48         28,700           1423550         Cispus River near         1,030         1947-90         1977         26.54         89,300         Nov. 25         23.60         66,300           14235500         Cowlitz River near         1,030         1947-90         1977         17.00         22,500         Nov. 24         14.44         17,600           14236200         Cowlitz River near <td></td> <td></td> <td></td> <td></td> <td>Wenatchee</td> <td>River Ba</td> <td>sin</td> <td></td> <td></td> <td></td> <td></td> <td></td>					Wenatchee	River Ba	sin					
12459000         Wenatchee River at Packed         1,000         1929-90         1948         15.88         32,300         Nov. 11         11.87         20,000           Peshastin, Washington         Wonatchee River at Monitor, Washington         1,301         1962-90         1980         27.23         29,600         Nov. 11         25.42         21,500           14226500         Cowlitz River         287         1929-90         1933         13.00         36,600         Nov. 24         12.48         28,700           1423500         Cispus River near Randle, Washington         321         1929-90         1974         12.58         21,700         Nov. 24         12.48         28,700           1423500         Cowlitz River near Randle, Washington         1,030         1947-90         1977         26.54         89,300         Nov. 25         23.60         66,300           14236200         Tillon River above Bear Canyon Creek near         141         1956-90         1977         17.00         22,500         Nov. 24         14.44         17,600	40	12457000	Wenatchee River at Plain, Washington	291	1910-79	1948	12.48	22,700	Nov. 11	10.52	17,000	10
Peshastin, Washington 12462500 Wenatchee River at 1,301 1962-90 1980 27.23 29,600 Nov. 11 25.42 21,500 Monitor, Washington 14226500 Cowlitz River at 1,301 1929-90 1933 13.00 36,600 Nov. 24 12.48 28,700 1422500 Cowlitz River near 321 1929-90 1974 12.58 21,700 Nov. 25 10.21 11,500 1423500 Cowlitz River near 1,030 1947-90 1977 26.54 89,300 Nov. 25 23.60 66,300 14236200 Tilton River above Bear 141 1956-90 1977 17.00 22,500 Nov. 24 14.44 17,600 Combat, Washington Company Washington	41	12459000	Wenatchee River at	000	1929-90	1948	15.88	32 300	Nov 11	11.87	20 000	
12462500         Wenatchee River at Monitor, Washington         1,301         1962-90         1980         27.23         29,600         Nov. 11         25.42         21,500           Monitor, Washington         Cowlitz River near Packwood, Washington         287         1929-90         1933         13.00         36,600         Nov. 24         12.48         28,700           14232500         Cispus River near Randle, Washington         321         1929-90         1974         12.58         21,700         Nov. 25         10.21         11,500           14233400         Cowlitz River near Randle, Washington         14236200         1947-90         1977         26.54         89,300         Nov. 25         23.60         66,300           14236200         Tillon River above Bear Canyon Creek near Cinebar, Washington         141         1956-90         1977         17,00         22,500         Nov. 24         14.44         17,600	:		Peshastin, Washington						Nov. 25	17.58	40,000	×100
Head of Conflict River Basin   Head of Conflict River Basin   Head of Conflict River Basin   Head of Conflict River Incomplete   Head of	42	12462500	Wenatchee River at	1,301	1962-90	1980	27.23	29,600	Nov. 11	25.42	21,500	15
14226500         Cowlitz River         287         1929-90         1933         13.00         36,600         Nov. 24         12.48           near Packwood, Washington         14232500         Cispus River near         321         1929-90         1974         12.58         21,700         Nov. 25         10.21           Randle, Washington         1,030         1947-90         1977         26.54         89,300         Nov. 25         23.60           Randle, Washington         14236200         Tilton River above Bear         141         1956-90         1977         17.00         22,500         Nov. 24         14.44           Canyon Creek near         Cinebat, Washington         Cinebat, Washington         Cinebat, Washington         14.44         14.44			Monitor, Washington		:	ć			Nov. 25	79.80	45,900	001×
14226500 Cowlite River 287 1929-90 1933 13.00 36,600 Nov. 24 12.48  near Packwood, Washington 14232500 Cispus River near 321 1929-90 1974 12.58 21,700 Nov. 25 10.21 Randle, Washington 14236200 Tilton River above Bear 141 1956-90 1977 17.00 22,500 Nov. 24 14.44 Canyon Creek near Cinebat, Washington					Cowlitz Ra	iver Basin						
14232500         Cispus River near         321         1929-90         1974         12.58         21,700         Nov. 25         10.21           Randle, Washington         1,030         1947-90         1977         26.54         89,300         Nov. 25         23.60           Randle, Washington         141         1956-90         1977         17.00         22,500         Nov. 24         14.44           Cinebar, Washington         Cinebar, W	43	14226500	Cowlitz River near Packwood, Washington	287	1929-90	1933	13.00	36,600	Nov. 24	12.48	28,700	15
14233400         Cowlitz River near         1,030         1947-90         1977         26.54         89,300         Nov. 25         23.60           Randle, Washington         Randle Washington         141         1956-90         1977         17.00         22,500         Nov. 24         14.44	4	14232500	Cispus River near Randle, Washington	321	1929-90	1974	12.58	21,700	Nov. 25	10.21	11,500	ς,
14236200 Tilton River above Bear 141 1936-90 1977 17.00 22,500 Nov. 24 14.44 Canyon Creek near Cinebar, Washington	45	14233400	Cowlitz River near Randle, Washington	1,030	1947-90	1977	26.54	89,300	Nov. 25	23.60	66,300	25
Canyon Creek near Cinebar, Washington	4	14236200	Tilton River above Bear	141	1956-90	1977	17.00	22.500	Nov. 24	14.44	17.600	01
Cittoda, Masimgion	}	007071	Canyon Creek near	Ē	0.000		00.11	000	7.00		200'11	2
			Cilicoar, washington									

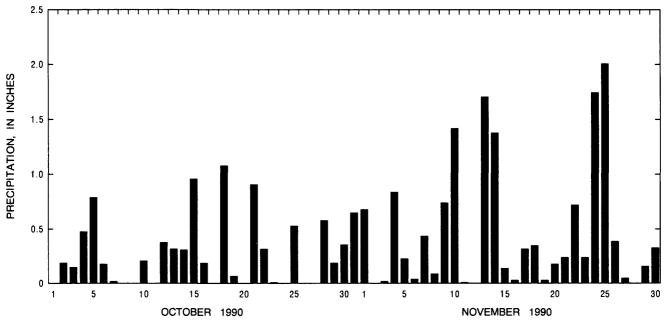


Figure 1. Daily precipitation at Mud Mountain Dam, Washington, October-November 1990.

Throughout most of western Washington, the largest quantities of precipitation fell during the second storm period of November 21-25. The Skagit River Basin may be an exception. The climatological station at Diablo Dam in the Skagit River Basin recorded 15.44 inches during the second 4-day storm (table 2, site 10), but the most intense rain was recorded November 10 when 7.32 inches fell in the 24-hour period at Diablo Dam (fig. 2).

During the period between the major storms, wet weather accompanied by cool temperatures continued and snow levels descended to about the 1,000 feet elevation. By November 21, 1990, snow depths in the Cascades averaged 6 inches at elevations of 1,000 to 2,000 feet; 12 inches at 2,000 to 3,000 feet; and 12 to 18 inches at 3,000 to 4,000 feet. The water content of the snow was generally 10 percent or higher. As a warm front moved through western Washington on Wednesday, November 21, snow changed to rain and temperatures rose. The warm front caused melting of snow to elevations of 7,500 feet in the northern Cascade Range and to about 5,500 feet in the Cascade Range at the southern end of the state. Over the next 3 days, intense rain fell on drainages where rivers were already swollen with snowmelt runoff; disastrous

flooding resulted. A cold front that moved in from the north on November 26, 1990, lowered freezing levels and diminished precipitation, finally ending the severe flooding.

#### THE FLOODS

As a result of the October-November 1990 storms, the western half of Washington experienced two major floods during November. The November 9-11 flooding affected streams in most of the northern half of western Washington on Veteran's Day weekend. The November 23-25 (during the week of Thanksgiving) floods affected streams in most of western Washington. The largest peaks ever observed in the Wenatchee River drainage on the east slopes of the Cascade Range were recorded November 25. With the exception of some rivers in the Skagit and Nooksack River Basins, most rivers in western Washington and the east slope of the Cascade Range experienced the most severe flooding during November 23-25.

#### **November 9-11 Floods**

The November 9-11 flooding was prevalent in the northern parts of western Washington. Severe flooding occurred in the Quinault, Queets, Snohomish, Skagit, and

**Table 2.** Precipitation totals for period November 7-11 and 21-25, 1990, at selected climatological stations in western Washington

Site		Precipitation, in	inches
number	Station	November 7-11	November 21-25
1	Grays River Hatchery	3.12	8.10
2	Centralia	1.15	6.06
3	Clearwater	6.59	8.05
4	Rainier Ohanapecosh	2.59	4.51
5	Mud Mountain Dam	2.70	4.96
6	Tolt South Fork Reservoir	6.24	7.30
7	Arlington	2.41	4.86
8	Stevens Pass	8.75	14.40
9	Lake Wenatchee	3.16	7.53
10	Diablo Dam	13.25	15.44

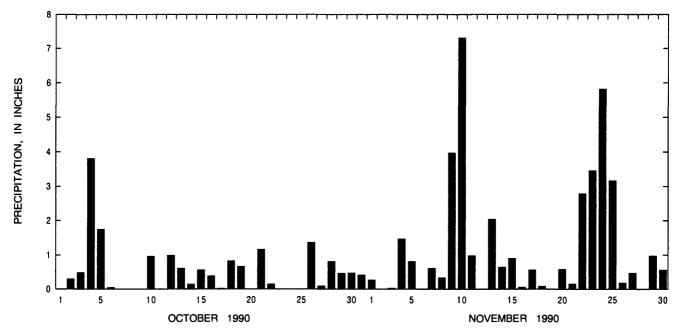


Figure 2. Daily precipitation at Diablo Dam, Washington, October-November 1990.

Nooksack Basins. The recurrence intervals for floods in these basins generally ranged from 10 to 30 years; The recurrence intervals for peak discharges at Skagit River Basin stations ranged from 15 to 50 years. On November 10, the peak flow for the Nooksack River at Deming was 37,900 ft<sup>3</sup>/s (cubic feet per second) [fig. 3].

Major flooding occurred on rivers that drain the east and west slopes of the Olympic Mountains in the coastal range. Recurrence intervals for floods on these rivers ranged from 5- to 25-year-flood events. The flood peak on the Quinault River slightly exceeded the November 24 flood event.

#### November 23-26 Floods

Severe flooding in Washington occurred November 23-26 in the Duwamish, Lake Washington, Snohomish, and Wenatchee River Basins. These floods were generally larger and more widespread than those earlier in the month, particularly in the Wenatchee River Basin (fig. 4). Flood peaks on the Snohomish River near Monroe and on three rivers in the

Wenatchee Basin equalled or exceeded the 100-year-flood event. The flood flow of the Wenatchee River at Plain was 1.3 times greater than the magnitude of the 100-year flood event. The flood peaks recorded November 24 or 25 were the highest ever observed at the following 11 gaging stations: Naselle River near Naselle (11,300 ft<sup>3</sup>/s), Willapa River near Willapa (11,800 ft<sup>3</sup>/s), Dungeness River near Sequim  $(7,120 \text{ ft}^3/\text{s})$ , Cedar River at Renton (10,600 s)ft<sup>3</sup>/s), Skykomish River near Gold Bar (102,000 ft<sup>3</sup>/s), Snoqualmie River near Snoqualmie (78,800 ft<sup>3</sup>/s), Raging River near Fall City (6,220 ft<sup>3</sup>/s), Snoqualmie River near Carnation (65,200 ft<sup>3</sup>/s), Wenatchee River at Plain ((33,200 ft<sup>3</sup>/s), Wenatchee River at Peshastin (40,000 ft<sup>3</sup>/s), and the Wenatchee River at Monitor  $(45,900 \text{ ft}^3/\text{s})$ .

#### THE DAMAGES

No final damage figures were available for the November flooding. All damage figures shown are based on preliminary estimates as presented by the U.S. National Oceanic and Atmospheric Administration (1991).

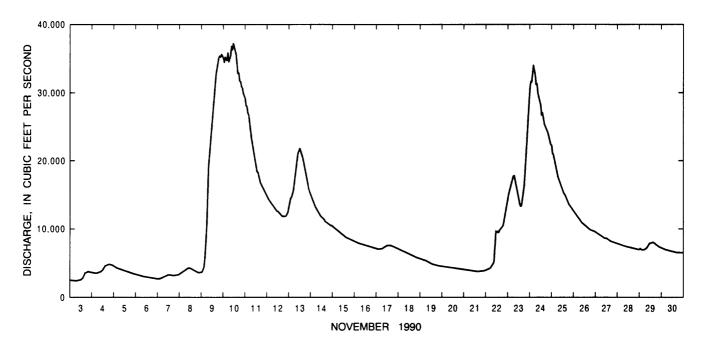


Figure 3. Discharge of Nooksack River at Deming, Washington, November 3-30, 1990.

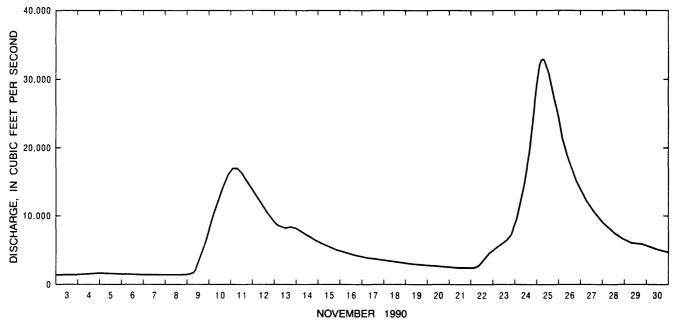


Figure 4. Discharge of Wenatchee River at Plain, Washington, November 3-30, 1990.

#### November 9-11

Extensive damages occurred as a result of the flooding. The Governor of Washington declared a state of emergency in Grays Harbor, King, Skagit, Snohomish, and Whatcom Counties. The flood waters of the Skagit River breached levees on Fir Island at the mouth of the river; approximately 500 people were evacuated and about 170 homes and farms were flooded. In Snohomish County, about 200 people were displaced from their homes. In Whatcom County, over 1,000 people on Gooseberry point and Lummi Island were isolated for a week. Estimated total flood damages were about 42 million dollars. Total damages to homes in Skagit, Snohomish, and Whatcom Counties were 14 million dollars, and damage to public works was about 24 million

dollars. Damages to homes in Skagit County were about 8 million dollars and in Whatcom County about 4 million dollars.

#### November 23-26

Two lives were lost as a direct result of the flooding. Large amounts of resources were expended for rescuing and evacuating about 2,000 residents from flooded areas. Some residents of Fir Island on the Skagit River were evacuated to escape rising floodwaters for the second time in the month of November. Thousands of homes were flooded in the affected areas; 42 homes were destroyed. Early estimates of damages to homes, farm structures, farm crops, livestock, roads, dikes, highway structures and other utilities were 100 million dollars.

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